

Soil Roughness Degradation and Crop Residue Decomposition: Measurement and Simulation

S. J. van Donk, USDA-ARS, Manhattan, KS, 66506, (E-mail: sdonk@weru.ksu.edu)

E. L. Skidmore, USDA-ARS, Manhattan, KS, 66506 (E-mail: skidmore@weru.ksu.edu)

Introduction

The United States Department of Agriculture (USDA) Agricultural Research Service (ARS) Wind Erosion Research Unit (WERU) in Manhattan, Kansas, USA is developing a process-based Wind Erosion Prediction System (WEPS), that is able to simulate wind erosion and dust emission for different management scenarios (Hagen, 1991; Wagner, 2001). WEPS consists of a number of submodels, including models for soil roughness degradation (Hagen et al., 1995) and crop residue decomposition (Steiner et al., 1995). Accurate prediction of wind erosion depends greatly on reliable simulations by these submodels. The objective of this study was to compare roughness degradation and residue decomposition, measured on a farmer's field near Burlington, Colorado, USA, with those simulated by WEPS.

Methods

Field measurements

Measurements, used in the present study, were taken in the context of a larger wind erosion field experiment, designed for testing the WEPS erosion submodel (van Donk and Skidmore, 2001). A field was selected 17 km south of Burlington, Colorado, USA (39.13 N, 102.30 W, elevation = 1292 m). A corn crop was grown on the field in the summer of 1998 and a sunflower crop in the summer of 1999. Wheat was planted on the 1720 m by 810 m field with a 305 mm row spacing on 29 August 2000. When we started field measurements in December 2000, the crop residue on the field was mainly corn. Measurements were taken at 15 locations on the NW corner (600 m by 415 m) of the field, on three dates: 19 December 2000, 8 March 2001, and 12 April 2001.

Ridge height for each field location was calculated as the average of the depths of four adjacent furrows, measured using a straight edge and a measuring tape. Soil random roughness was measured using a pinmeter (Wagner and Yu, 1991), positioned in parallel with a ridge. Pinmeter photographs were taken using a digital camera and analyzed using SigmaScan Pro (SPSS Inc., Chicago, IL) software. Random roughness was calculated as the standard deviation of pin positions (Allmaras, 1966), which was corrected for trends, i.e. downward or upward trends of pin positions from one side of the pinmeter to other. Such trends increase the standard deviation without contributing to soil roughness.

Above ground flat corn residue was collected within a rectangular frame of 305 mm by 584 mm. Dirt was removed from the residue using various hand tools. The residue was air dried and weighed in the laboratory. Flat residue cover was measured using a 15.2 m (50 ft) long measuring tape, counting the foot marks that covered pieces of residue. No standing residue was present on the field.

A weather station was centrally located on the NW corner of the field. Measurements included air temperature at 2.0 m (CS500, Campbell Scientific, Logan, UT¹) and precipitation using a tipping bucket rain gauge (6010, Qualimetrics). The sensors were calibrated before being deployed in the field. Data were measured and recorded with a data logger (CR10X) and a solid state multiplexer (25AMT) from Campbell Scientific. Sensors were sampled every 10 s and data were recorded for 15 minute periods.

Simulations

The amount of precipitation is critical, especially for the simulation of the degradation of ridge height and random roughness. During the snowy period from 19 December 2000 through 8 March 2001, precipitation measured on our field differed greatly from that measured at nearby stations (Table 1). For the period from 9 March to 12 April 2001, when precipitation came mostly in the form of rain, the three stations agreed well with each other. The windswept Great Plains is a very difficult area to accurately measure the water content of snow. Using ASOS type rain gauges (the type used at Burlington airport), the office of the Colorado State Climatologist conducted a study, that showed substantial undermeasurement of snow, down to as little as 10% of actual precipitation. Errors are not linear, and are not easily corrected (Nolan Doesken, Assistant State Climatologist; personal communication).

Thus, it is very likely that Burlington airport underestimated precipitation during the winter. On

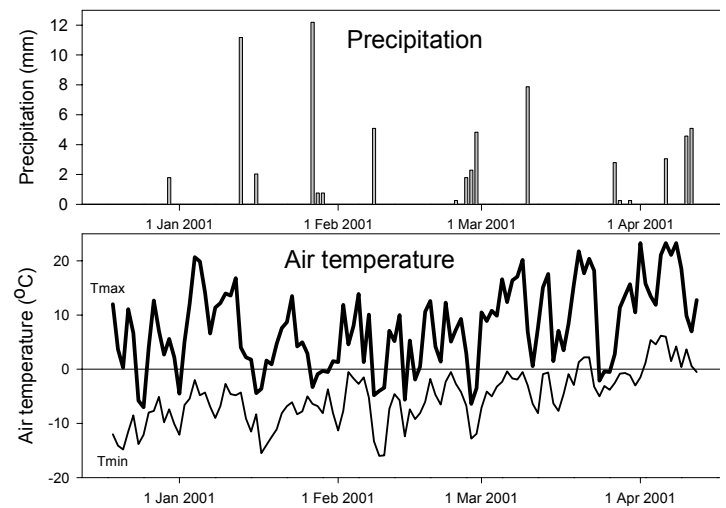


Figure 1. Daily precipitation (Burlington 4S) and air temperature (field).

Table 1. Precipitation (mm) measured at three nearby stations. Burlington airport and Burlington 4S are both 10 km north of the field. Precipitation from Burlington 4S and the fictitious ‘scenario 2’ were used in the simulations.

Station	19 Dec. to 8 Mar.	9 Mar. to 12 Apr.
	8 Mar.	12 Apr.
Field	8	21
Burlington airport	21	22
Burlington 4S	43	24
Scenario 2	63	24

our field we measured even less (Table 1). Therefore, simulations were conducted using precipitation from Burlington 4S, the station that reported the most precipitation during the winter (Table 1, Figure 1). Because of the uncertainty in precipitation, additional simulations were conducted using precipitation ‘scenario 2’

¹ Mention of brand names is for information purposes only and does not imply endorsement by USDA-ARS.

(Table 1), that was constructed by tripling the winter precipitation of Burlington airport ($3 \times 21 = 63$ mm). This scenario seems reasonable, considering that the ASOS type rain gauge used at Burlington airport underestimates snow up to 10 times.

The model for ridge height degradation is based on research by Lyles and Tatarko (1987). The model for random roughness degradation is based on work described by Zobeck and Onstad (1987) and Potter (1990). In WEPS, roughness simulation has to start immediately following roughness creation. Thus, we started simulations on the day of wheat planting (29 August 2000). Simulated ridge height and random roughness were forced to match the mean of the measured values on the first day of measurement (19 December 2000, Figure 2). No wind erosion occurred between 19 December and 12 April, so all roughness degradation was due to precipitation during this period.

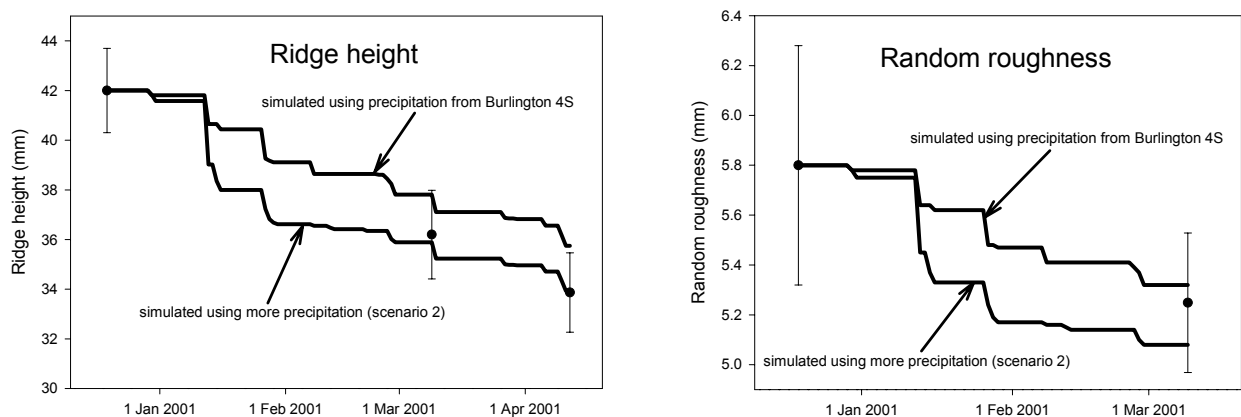


Figure 2. Simulated (with two different precipitation scenarios, see Table 1) and measured ridge height and random roughness. Simulations were forced to coincide with the mean of the measured values on 19 December 2000. Measurements were taken at 15 locations on a 600 by 415 m field. Vertical bars are ± 1 SE of the mean ($n = 15$).

Total biomass (dead crop residue plus live wheat plants) cover was estimated between 0 and 30% throughout the period of simulation. Within this range, simulated ridge height and random roughness changed little, so a more accurate estimate of biomass cover was not critical for this study. A constant biomass cover of 15% was used for all roughness simulations.

Research underlying the WEPS residue decomposition model has been reported by Schomberg et al. (1994, 1996) and by Schomberg and Steiner (1997). Decomposition greatly depends on temperature and moisture, as well as on the type of crop. For flat residue, WEPS considers both precipitation and soil water content. Since we didn't have soil water content data, we only used precipitation (from Burlington 4S) for the simulation, which would underestimate decomposition. We, therefore, also simulated with moisture being at its optimum for decomposition, which would overestimate decomposition (Figure 3).

Results and discussion

Using precipitation from Burlington 4S, ridge height seemed overestimated (Figure 2), but the difference between simulation and measurement was not

significant ($P = 0.05$). Random roughness seemed slightly overestimated, but this was not significant either. Furthermore, when simulating using precipitation scenario 2 (Table 1), measured and simulated ridge height matched almost exactly and random roughness was underestimated, but not significantly (Figure 2). WEPS treats rain and snow the same. In reality, it may be expected that rain reduces roughness more than snow, due to its higher impact energy. Refinement of the model in this respect may be warranted.

Simulated residue decomposition was little, no matter what we assumed for moisture (Figure 3). Temperature was the most limiting factor. Decomposition picked up with warming in the spring (Figures 1 and 3). On 9 March measured residue biomass seemed greater than on 19 December, but the difference is not significant ($P = 0.05$). Simulated and measured corn residue biomass did not differ significantly from each other either.

NRCS personnel have measured 7 - 39% loss of residue biomass during the period October - March in the Northern USA (Montana, Wyoming, North Dakota). Measurements included stems, leaves, chaff, etc. (Gary Tibke, personal communication). WEPS predicted, and measurements showed, very little decomposition at Burlington, Colorado (Figure 3), where temperatures were at least as warm as those during the NRCS measurements. At least two reasons may explain this discrepancy: 1) At harvest, WEPS disregards everything but stems. Thus, subsequent decomposition only includes stems, which decompose slower than leaves and chaff. If the NRCS had measured only the loss of stem mass, losses likely would have been much smaller. 2) Some of the decrease in residue mass, measured by the NRCS, may be due to removal by wind rather than decomposition.

Conclusions

On a farmer's field near Burlington, Colorado, USA, the mean ridge height of 42 mm on 19 December 2000 was reduced to 34 mm (36 mm simulated using WEPS) on 12 April 2001. The mean random roughness of 5.8 mm on 19 December was reduced to 5.2 mm (5.3 mm simulated) on 9 March. The simulation of roughness degradation is driven by precipitation, which is very difficult to measure in windy climates, especially when it comes in the form of snow. The mean corn residue biomass of 1204 kg ha^{-1} on 19 December was only reduced slightly to 1174 kg ha^{-1} ($1144 - 1186 \text{ kg ha}^{-1}$ simulated) on 12 April. None of the differences between measured data and simulations were significant ($P = 0.05$), enhancing confidence in the ability of WEPS to simulate roughness degradation and residue decomposition.

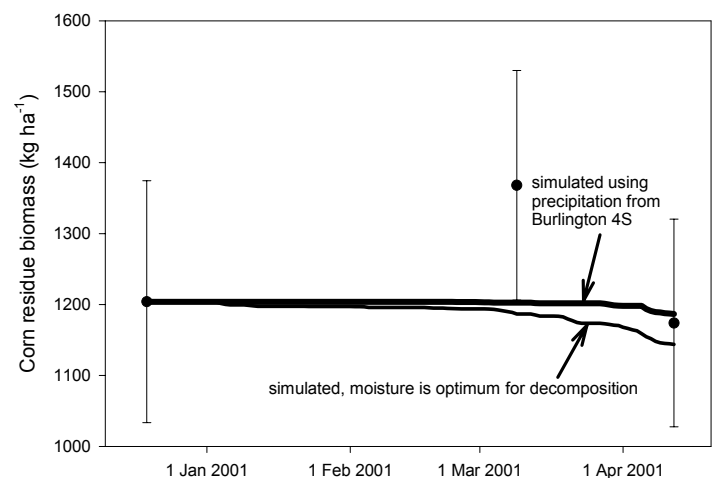


Figure 3. Simulated and measured corn residue biomass. Simulations were initialized at the mean of the measured values on 19 December 2000 (1204 kg ha^{-1}). Corn residue biomass samples were taken at 15 locations on a 600 by 415 m field. Vertical bars are $\pm 1 \text{ SE}$ of the mean ($n = 15$).

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